

**CEMENTING SUBTERRANEAN
ZONES USING CEMENT COMPOSITIONS
CONTAINING BIODEGRADABLE DISPERSANTS**

Background of the Invention

1. Field of the Invention.

[0001] The present invention relates to methods of cementing subterranean zones using cement compositions containing biodegradable dispersants.

2. Description of the Prior Art.

[0002] In the cementing of oil and gas wells and the like, dispersants are extensively used to reduce the rheologies of cement compositions, i.e., the apparent viscosities and other properties of the cement compositions, as well as to reduce the water content of the cement compositions. The reduction of the rheology of a cement composition allows the cement composition to be pumped with less friction pressure which utilizes less pump horsepower. In addition, the lower rheology often allows the cement composition to be pumped in turbulent flow. Turbulent flow characteristics are desirable when pumping cement compositions in oil and gas wells to more efficiently remove drilling fluid from surfaces in the well bore as the drilling fluid is displaced by the cement composition being pumped. The inclusion of dispersants in cement compositions is also desirable in that the presence of the dispersants reduces the water required for preparation of the cement compositions. Cement compositions having reduced water content are characterized by improved compressive strength development.

[0003] A number of dispersing agents have been utilized heretofore in cement compositions, particularly in cement compositions used for primary and remedial cementing in

oil and gas wells. For example, certain organic acids such as gluconic acid and citric acid have been recognized by those skilled in the art as cement dispersants. However, such organic acids are also strong cement composition set retarding agents which is often undesirable. That is, the presence of an organic acid dispersant in a cement composition prevents the cement composition from setting for a relatively long period of time which is often costly or otherwise detrimental. Other dispersants which are commonly used in hydraulic cement compositions include polynaphthylene sulfonate which is commercially available under the trade designation "CFR-2™" from Halliburton Energy Services of Duncan, Oklahoma, the condensation product of formaldehyde, acetone and a sulfite which is commercially available under the trade designation "CFR-3™" from Halliburton Energy Services, poly-B-naphthol sulfonate, polymelamine sulfonate and many others. Another highly efficient dispersant for use in cement compositions is disclosed in U.S. Patent No. 6,136,950 issued to Vickers, Jr. et al. on October 24, 2000 which is incorporated herein by reference. The dispersant is a polycarboxylate polymer comprised of a functionalized polyamide main chain polymer onto which are grafted at least some oligomeric or polymeric hydrophilic side chains. Commercially available dispersants are generally not environmentally acceptable, especially in offshore operations, in that they do not undergo complete biodegradation in the environment and can cause damage to aquatic and other life therein.

[0004] Thus, there are needs for improved methods of cementing subterranean zones penetrated by well bores using cement compositions containing biodegradable dispersants.

Summary of the Invention

[0005] The present invention provides methods of using improved cement compositions containing biodegradable dispersants for cementing subterranean zones penetrated by well bores

which meet the needs described above and overcome the deficiencies of the prior art. The cement compositions which are useful in accordance with the methods of this invention are basically comprised of a hydraulic cement, a biodegradable dispersant comprised of polyaspartic acid containing side chains formed by reacting one or more side chain forming chemicals with said polyaspartic acid and sufficient water to form a pumpable slurry. The side chain containing biodegradable dispersant is present in an amount sufficient to reduce the rheology and water content of the cement composition. Preferably, the side chain containing polyaspartic acid dispersant has a molecular weight in the range of from about 5,000 to about 500,000 daltons.

[0006] The methods of cementing a subterranean zone penetrated by a well bore of this invention are basically comprised of the following steps. A cement composition is prepared comprised of a hydraulic cement, a biodegradable dispersant comprised of the above described side chain containing polyaspartic acid present in an amount sufficient to reduce the rheology and water content of the cement composition and sufficient water to form a pumpable slurry. Thereafter, the cement composition is placed in the subterranean zone to be cemented and is allowed to set into an impermeable solid mass therein.

[0007] In addition to functioning as a cement composition rheology and water content reducing dispersant, the side chain containing polyaspartic acid also functions to enhance the effectiveness of a fluid loss control agent when such an agent is included in the cement composition. For example, a hydroxyethylcellulose or a polyethylene imine fluid loss control agent can be included in the cement composition and the side chain containing polyaspartic acid therein functions with the fluid loss control agent to reduce fluid loss to a substantially greater degree than when the side chain containing polyaspartic acid is not present.

[0008] Thus, it is a general object of the present invention to provide improved methods of cementing subterranean zones using cement compositions containing biodegradable dispersants.

[0009] Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of preferred embodiments which follows.

Description of Preferred Embodiments

[00010] As mentioned, the improved methods of this invention utilize cement compositions basically comprised of a hydraulic cement, a biodegradable dispersant comprised of polyaspartic acid containing side chains present in an amount sufficient to reduce the rheology and water content of the cement composition and sufficient water to form a pumpable slurry.

[00011] The biodegradable side chain containing polyaspartic acid dispersant can be prepared by the condensation reaction of maleic acid and ammonia under heat. The polyaspartic acid formed is then reacted with a side chain forming chemical. The side chain forming chemical can be one or more of ethylene oxide, propylene oxide, a vinyl functional polyethylene glycol, a vinyl functional polypropylene glycol, an amino functional polyethylene glycol (the most preferred being those terminated by an NH_2 group), a polyester, a polyamide, polyethyleneoxide, polypropyleneoxide and the like. The molecular weight of the resulting side chain containing polyaspartic acid is increased to in the range of from about 5,000 to about 500,000 daltons. The formation of the side chains on the polyaspartic acid reduces the cement set retarding properties of the acid in addition to reducing the rheology and water content of cement compositions to which it is added. The side chain containing polyaspartic acid dispersant is included in a cement composition in a relatively small amount, i.e., an amount in the range of

from about 0.10% to about 2.0% by weight of cement therein, preferably in an amount of about 0.20%.

[00012] A variety of hydraulic cements can be utilized in accordance with the present invention including those comprised of calcium, aluminum, silicon, oxygen and/or sulfur which set and harden by reaction with water. Such hydraulic cements include, but are not limited to, Portland cements, pozzolana cements, gypsum cements, high alumina content cements, silica cements and high alkalinity cements. Portland cements are generally preferred for use in accordance with the present invention, and Portland cements of the types defined and described in API Specification For Materials And Testing For Well Cements, API Specification 10, 5th Edition, dated July 1, 1990 of the American Petroleum Institute and their equivalents are particularly preferred. API Portland cements including classes A, B, C, G and H can be utilized with API classes G and H being preferred and class H being the most preferred.

[00013] The water utilized in the cement compositions of this invention can be fresh water, unsaturated salt water and saturated salt water including brines or seawater. Generally, the water can be from any source provided it does not contain an excess of compounds that adversely affect other components in the cement compositions. The water is present in a cement composition of this invention in an amount sufficient to form a pumpable slurry. More particularly, the water is present in the cement compositions in an amount in the range of from about 18% to about 110% by weight of hydraulic cement therein, more preferably in an amount of from about 25% to about 56%.

[00014] As mentioned, the cement compositions of this invention can also include a fluid loss control additive which when utilized in combination with the biodegradable dispersant of this invention provides synergistically low fluid loss from the cement composition. Examples of

fluid loss control agents which can be utilized in combination with the biodegradable dispersants of this invention, include, but are not limited to, hydroxyethylcellulose, hydroxymethylcellulose, carboxymethylhydroxyethylcellulose, hydroxypropylcellulose, a copolymer of 2-acrylamido-2-methyl propane sulfonic acid and N,N-dimethylacrylamide, a graft lignin or lignite polymer, starch, guar gum, hydroxypropylguar, polyethyleneimine, polyvinylalcohol, polyvinylacetate, carragenan and xanthane. Of these, hydroxyethylcellulose is preferred. When used, the fluid loss control additive is included in a cement composition of this invention in an amount in the range of from about 0.2% to about 2.0% by weight of cement therein.

[00015] The biodegradable side chain containing polyaspartic acid dispersants of this invention can be effectively utilized in cement compositions which are subjected to temperatures in the range of from about 32°F to about 500°F. The cement composition densities utilized can range from about 0.66 to about 2.50 kilograms per liter. As mentioned, the biodegradable side chain containing polyaspartic acid dispersants of this invention are biodegradable and nontoxic.

[00016] As will be understood by those skilled in the art, when the cement compositions of this invention are utilized for cementing subterranean zones penetrated by well bores, they can also include a variety of other conventional well cement additives. For example, the cement compositions can include weighting materials, set retarding additives, set accelerators, strength stabilizers, strength enhancers, lightweight additives, anti-gas migration additives, defoamers, foamers, expansion additives and the like.

[00017] The methods of the present invention for cementing a subterranean zone penetrated by a well bore basically comprise the following steps: (a) preparing a cement composition of this invention comprised of a hydraulic cement, a biodegradable dispersant comprised of side chain containing polyaspartic acid present in an amount sufficient to reduce

the rheology and water content of the cement composition and sufficient water to form a pumpable slurry, (b) placing the cement composition in the zone to be cemented and (c) allowing the cement composition to set into an impermeable solid mass therein.

[00018] As mentioned above, the cement compositions of this invention containing the above described biodegradable dispersant have reduced rheology and reduced water content as compared to cement compositions which do not include the biodegradable dispersant. The lower rheology of the cement composition allows the cement composition to be pumped with less friction pressure utilizing less pump horsepower. The lower rheology also allows the cement composition to be pumped in turbulent flow which is highly advantageous in primary cementing operations. The reduced water content of the cement compositions of this invention substantially improves the compressive strengths of the cement compositions when set. As also mentioned above, the biodegradable dispersant utilized in the cement compositions of this invention synergistically function in combination with certain fluid loss control agents to reduce the fluid loss from the cement compositions to a substantially greater degree than cement compositions which include the fluid loss control agent but not the biodegradable dispersant.

[00019] In order to further illustrate the cement compositions and methods of the present invention, the following examples are given.

Example 1

[00020] Test cement compositions were prepared containing fresh water, Dyckerhoff API Class G Portland cement and a biodegradable dispersant of this invention, i.e., an ethylene oxide side chain containing polyaspartic acid having a molecular weight of about 10,000 daltons. The thickening times of the test cement compositions at 125°F, the rheology of the cement compositions after preparation at room temperature, the rheology of the cement compositions

after conditioning at 125°F, the free water of the cement compositions, the settling of the cement compositions and the compressive strengths of the cement compositions at 3,000 psi and 125°F were determined. The quantities of the components in the test cement compositions and the test results are given in Table I below.

TABLE I
Effect Of Concentration On Rheology

Test Cement Composition No.	1	2	3	4
Fresh Water, % by wt. of cement	44	44	44	44
Ethylene Oxide Side Chain Containing Polyaspartic Acid, % by wt. of cement	0.1	0.2	0.3	0.4
Class G Cement, kilograms	100	100	100	100
Cement Composition Density, kilograms/liter	1.92	1.92	1.92	1.92
<u>Thickening Time at 125°F</u>				
30 Bc	2:57	5:43	-	-
70 Bc	3:30	6:09	-	-
100 Bc	3:37	6:17	-	-
<u>Rheology After Preparation At Room Temperature</u>				
300-200-100-	25-17-9	29-18-9	25-16-18	23-15-8
60-30-6-3 rpm	6-4-3-2	6-3.5-2-1.5	5-3-2-1	4-3-2-1
<u>Rheology After Conditioning At 125°F</u>				
300-200-100-	30-22-13	21-13-7	12-8-4	12-8-4
60-30-6-3 rpm	10-8-6-5	4-3-2-1.5	3-2-2-1	3-2-2-1
<u>Free Water, % by vol.</u>	9	16	44	38
<u>Settling, % by vol.</u>	0	4.8	56	62
<u>Universal Cement Analyzer Data</u>				
50 psi, Hrs:Min	7:44	-	-	-
500 psi, Hrs:Min	9:15	10:02	-	-
24 Hrs, psi	4161	2500	set	set
72 Hrs, psi	5843	4141	-	-

[00021] As shown in Table I, the improved cement compositions of this invention containing a biodegradable dispersant comprised of ethylene oxide side chain containing polyaspartic acid have excellent properties. While the thickening times, the free water, settling and the set times increase with increased dispersant concentrations, at concentrations of the biodegradable dispersant below about 0.3% by weight of cement, the dispersant provides excellent cement composition properties.

Example 2

[00022] Additional test cement compositions were prepared utilizing fresh water and Dyckerhoff API Class G Portland cement. Test Cement Composition No. 1 contained only fresh water, cement and hydroxyethylcellulose fluid loss control agent. Test Cement Composition No. 2 contained fresh water, cement, the dispersant of this invention and hydroxyethylcellulose fluid loss control agent. The rheologies after preparation at room temperature and after conditioning at 125°F were determined as well as the fluid loss from the test cement compositions at 125°F. The quantities of the components and the results of the tests are given in Table II below.

TABLE II
Synergistic Effect With Fluid Loss Control Additives

Test Cement Composition No.	#1	#2
Fresh Water, % by wt. of cement	45	45
Ethylene Oxide Side Chain Containing Polyaspartic Acid, % by wt. of cement	0	0.2
Hydroxyethylcellulose Fluid Loss Agent, % by wt. of cement	0.75	0.75
Class G Cement, kilograms	100	100
Cement Composition Density, kilograms/liter	1.9	1.9
<u>Rheology After Preparation At Room Temperature</u>		
300-200-100	128-89-48	136-90-44
60-30-6-3	30-17-5-3	25-12-2-1
<u>Rheology After Conditioning At 125°F</u>		
300-200-100	128-100-69	70-45-22
60-30-6-3	55-43-31-28	13-6-1-0
<u>API Fluid Loss At 125°F, ml/30 min</u>	245	60

[00023] As shown in Table II, the cement composition containing the dispersant of the present invention (Test Cement Composition No. 2) produced lower rheology and substantially less fluid loss than the cement composition without the dispersant (Test Cement Composition No. 1).

Example 3

[00024] Additional test cement compositions were prepared comprised of water, Dyckerhoff Class G cement and the biodegradable dispersant of this invention. The test compositions included varying amounts of water, but the same amounts of cement and dispersant. The rheologies of the test cement compositions after preparation at room temperature and after conditioning at 125°F were determined as well as the set times and compressive strengths of the cement compositions. The results of these tests are set forth in Table III below.

TABLE III
Water Reducing Properties

Test Cement Composition No.	1	2	3	4
Fresh Water, % by wt. of cement	44	35	30	25
Ethylene Oxide Side Chain Containing Polyaspartic Acid, % by wt. of cement	0.2	0.2	0.2	0.2
Class G Cement, kilograms	100	100	100	100
Cement Composition Density, kilograms/liter	1.92	2.03	2.11	2.21
<u>Rheology After Preparation At Room Temperature</u>				
300-200-100-	29-18-9	67-41-18	163-95-36	300+-243-94
60-30-6-3	6-3.5-2-1.5	10-5-3-2	17-6-1-0	45-15-1.5-0
<u>Rheology After Conditioning At 125°F</u>				
300-200-100-	21-13-7	38-21-8	119-70-30	300+-211-94
60-30-6-3	4-3-2-1.5	4-2-1-0	16-7-1-0	47-24-3-2
<u>Universal Cement Analyzer Data</u>				
50 psi, Hrs:Min	-	5:36	4:39	4:32
500 psi, Hrs:Min	10:02	6:38	5:26	5:08
24 Hrs, psi	2500	6000	6547	9000
72 Hrs, psi	4141	7531	-	10529

[00025] From Table III it can be seen that the biodegradable dispersant of this invention reduces the water content required while maintaining pumpability. In addition, the set cement compositions have excellent compressive strengths.

Example 4

[00026] Three additional cement compositions of this invention were prepared comprised of salt water containing various concentrations of salt, the biodegradable dispersant of this invention and Dyckerhoff Class G cement. The rheologies of the test compositions after preparation at room temperature and after conditioning at 125°F were determined as well as the set times and compressive strengths of the cement compositions. The results of these tests are set forth in Table IV below.

TABLE IV
Salt Tolerance

Test Cement Composition No.	1	2	3
Fresh Water, % by wt. of cement	44	44	44
Ethylene Oxide Side Chain Containing Polyspartic Acid, % by wt. of cement	0.2	0.2	0.2
Salt (NaCl), % by weight of water	10	18	37
Class G Cement, kilograms	100	100	100
Cement Composition Density, kilograms/liter	1.93	1.95	1.96
<u>Rheology After Preparation At Room Temperature</u>			
300-200-100-	23-14-6	22-14-7	27-18-10
60-30-6-3 rpm	3-1-0-0	3-1-0-0	6-3-2-1
<u>Rheology After Conditioning At 125°F</u>			
300-200-100-	18-13-6	11-7-4	20-15-9
60-30-6-3 rpm	3-2-0-0	2-1.5-00	7-5-3-2
<u>Universal Cement Analyzer Data</u>			
50 psi, Hrs:Min	8:05	11:47	47:45
500 psi, Hrs:Min	9:43	13:31	51:15
24 Hrs, psi	2400	3800	-
72 Hrs, psi	3344	5107	3047

[00027] From Table IV it can be seen that the biodegradable dispersant of this invention is salt tolerant and that the rheologies of the test cement compositions were low even when the salt water was saturated at 37% salt by weight of water. While the set times are somewhat longer, the compressive strengths are excellent.

[00028] Thus, the improved methods of this invention are well adapted to carry out the objects and attain the ends and advantages mentioned as well as those which are inherent therein. While numerous changes may be made by those skilled in the art, such changes are encompassed within the spirit of this invention as defined by the appended claims.

[00029] What is claimed is: